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HEAT TREATMENT EFFECT ON STRUCTURE AND MECHANICAL PROPERTIES OF SPD HIGH PURITY TITANIUM

Titanium and its alloys are widely used in engineering. Pure titanium possesses high biologic compatibility, and provided its strength is increased, it holds much promise for medical implants. Its properties can be optimized by forming ultra-fine grain structure through severe plastic deformation (SPD) combined with programmed heat treatment.

The present investigation was aimed at studying of the effect of isochronous annealing temperature on microstructure evolution and mechanical properties of pure titanium that had been subjected SPD by the upsetting–extrusion–drawing route. Iodine titanium was used for the research. After SPD-treatment, the titanium samples were studied in uniaxial tension in both initial and annealed (T_{ann} = 150–550°C, t = 1 h) states. Optical and electron microscopy were applied to study the structure of the samples. Microhardness H_{μ} of all the samples was measured.

The sample state effects on stress-strain curves and their parameters, $\sigma_{0.2}$, σ_b, σ_p, δ_p, δ, ψ, as well as H_{μ}, were investigated. Correlation between the parameters and the microstructure features was traced. It was shown that the applied SPD route, being a combination of simple processes, i.e. upsetting, extrusion, drawing, efficiently refines grains in the high purity titanium and permits the microstructure state of 150 nm in the mean grain size to be obtained. A required combination of strength and plastic properties of SPD high purity titanium can be realized by optimizing annealing temperature near 350°C and varying the heat treatment time.

Keywords: iodine titanium, severe plastic deformation, annealing, structure, mechanical properties

Fig. 1. Titanium sample structure in the initial SPD-state (*а*) and after annealing for 1 h at 300 (*б*), 350 (*в*), and 550°C (*г*) (transmission electron microscopy)

Fig. 2. Fracture surfaces of the initial sample (*а*) and samples annealed at 300 (*б*), 350 (*в*), and 550°C (*г*)

Fig. 3. Experimental loading curves of SPD titanium samples, annealed at various temperatures T_{ann}, °C: *2* – 350, *3* – 450, *4* – 550; curve *1* corresponds to the samples in the initial (i.e. deformed) state; the curves of the samples annealed at 150, 250 and 300°C are similar

Fig. 4. Annealing temperature dependences of strength parameters of the samples

Fig. 5. Annealing temperature dependences of plasticity parameters of the samples

Fig. 6. Annealing temperature dependences of the head (●) and neck (○) microhardness of the samples

Fig. 7. Relative changes of the strength (*а*) and plasticity (*б*) parameters of the samples vs annealing temperature

Fig. 8. $\sigma_{0.2}$ and σ_p changes (after annealing) relative to σ_b vs annealing temperature

Fig. 9. $\sigma_{0.2}$ and σ_b ratio to H_{μ}^h and H_{μ}^n vs annealing temperature: ● – $\sigma_{0.2} / H_{\mu}^n$, ○ – $\sigma_{0.2} / H_{\mu}^h$, ■ – σ_b / H_{μ}^n, □ – σ_b / H_{μ}^h